Browsing the World:
bridging pervasive computing and the Web

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EXTENDED ABSTRACT

The final version of the paper will include technical details on the proposed architecture, its implementation, and the services integrated within it. Also, it will extensively discuss related works, other proposals in the area, and will discuss open issues and research directions.

1. INTRODUCTION

The recent availability of innovative and open Geographic Information Systems (GIS) relying on standard Web technologies (e.g., Google Maps (maps.google.com), and Google Earth (earth.google.com)), together with the increasing availability of pervasive computing devices such as wireless sensors and RFID tags [WerL06, Wan06] will extend the concept of browsing.

In the next few years, we will no longer simply browse the web, but will be able to browse the world around us: we will seamlessly access both data coming form the physical environment via pervasive sensors and data coming form the web, and we will be able to integrate them as needed in suitable spatial framework, as it can be provided by open GIS.

The concept of browsing the world represents a very natural paradigm which promise to be useful for a number of services. The possibility of looking for information about things and facts on the basis of their location and their actual real-time status (e.g., find the closest Chinese restaurant which is not fully booked) is indeed of a much higher values than currently provided by Web.

In this context, GIS are the most natural tools to represent pervasive computing and data typically coming from the physical world. For example, the data collected from a sensor network could be effectively depicted *on* the place in which they are collected. This kind of visualization can be very useful to understand possible correlations between the data and its location. For example, a sensor network detecting some kind of polluting agent could visualize collected data on a map showing nearby industrial implants to discover possible causes of the pollution, or in a map showing natural

reserves to predict dangerous effects. However, while GIS visualization of sensor data and information has a long history [GIS], only the recent availability of open GIS tools such as Google Earth (consenting any user/developer to enrich the GIS with any needed custom data) and based on Web standards (consenting a painless integration with Web information) will make the “browsing the world” vision a common practice.

The goal of this paper is to present our current efforts in making the above vision real. In particular, we describe the software infrastructure we have realized to enable users to seamlessly navigate the physical world (by accessing RFID tags in the environment), the Web world (via WiFi or cellular telephony), integrate and contextualize the retrieved information (via GPS localization), and make the results available in Google Earth. A number of simple, yet very useful, services that we have integrated within the infrastructure are also described.

2. BROWSING THE WORLD: INFRASTRUCTURE AND SERVICES

To enable the above vision, it is fundamental to have a reference infrastructure allowing to collect, integrate, and present the data in a proper geographic representation. In this section, we describe a general-purpose infrastructure to enable browsing the world that we have implemented in a simple way by using low-cost commercial technologies. Then, we sketch some examples of services that we developed on top of it.

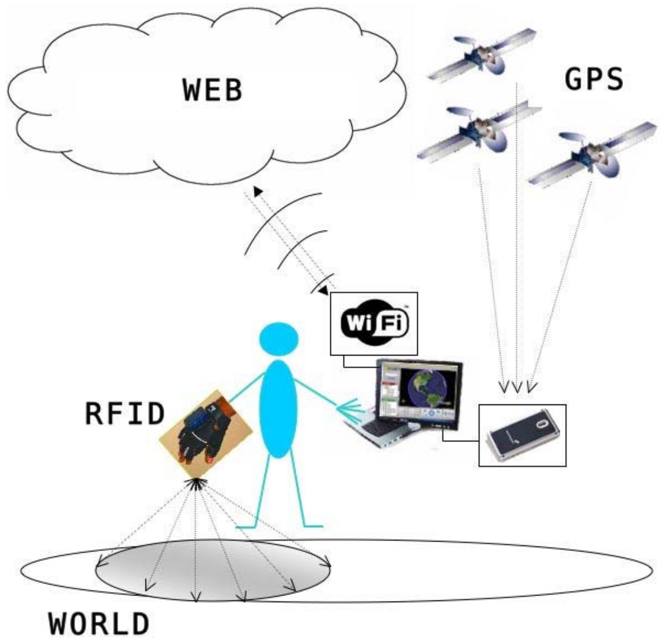

Figure 1. System architecture

2.1 Infrastructure

A general infrastructure to enable human-centric browsing of the world must include services for data acquisition, data integration, and data visualization.

The architecture we have implemented (and that we will describe extensively in the final version of the paper) is organized as follows (see Fig. 1):

1. Putting humans at the center, our architecture considers users with a portable computing device (i.e., laptops), integrating localization devices (i.e., GPS), devices to acquire information from the physical world (i.e., RFID readers), and means to connect to the Internet (i.e., WiFi and/or UMTS connections). All of which to be integrated into a GIS (Google Earth) perspective, by having a Google Earth client running on the user computer device.
2. A number of devices can be used to acquire data from the physical world and transform it with a well-specified format. In our current implementation, RFID readers (in the form of a wearable glove) can be used to collect information from dispersed RFID tags in the environment. This information, enriched with the physical location where it has been collected (as provided by the GPS device) flows into a local tuple space [MamQZ06]. The collection of such data is realized through Java classes accessing low-level device controller (written in C) via JNI, and transforming them into tuples. In addition, sensor network nodes (Crossbow MICAz) can be used to connect, via ZigBee, to other sensors in the environment, and act as source of data for the local tuple space server. At the time of writing this extended abstract, though, the integration of Crossbow motes is still not working properly.
3. The data coming from the GPS too is considered as information related to something happening in the physical world (i.e., “the user X is in that position”).
4. An application running locally on the user portable device continuously collects data from the physical world (there included the current GPS position of the user) by accessing the local tuple space. Then, it interfaces with the local Google Earth client and turn data into a user-centric perspective. More in detail, we customized Google Earth visualization by: *(i)* centering on the current GPS position of the user; *(ii)* transforming the information coming from the physical world into the KML language (which is a XML application). Since KML enables enriching geographical images with custom annotations, and since KML information

can be fed dynamically into Google Earth, users can obtain a dynamic real-time visualization of what is currently around them.

5. Other than from the physical world, the application can dynamically connect to the Web to retrieve additional KML information (as well as any kind of Web information) to integrate that coming from the physical world. On the one hand, one can rely on existing known third-part Web servers to retrieve such information. On the other hand, any specific application can provide KML-formatted data describing application-specific information (e.g., the actual positions of specific users and the data they collected via RFID readings) and make it dynamically available. For our own purposes, we have implemented such servers by using Apache Tomcat and by writing a number of simple JSPs.

As additional notes, we want to emphasize here that:

1. The implemented infrastructure, although being human-centric, would work equally well if, instead of mobile users, it would use mobile robots or fixed data server as data collectors (having the goal of dynamically collecting physical data and make it available on some Web servers). This is particularly important because it can enable a user, to access, other than the information about the physical world nearby, also real-time updated information coming from farther regions of the world. This can occur because the user, can integrate in a seamless way the information about the physical world that he directly perceive together with the information about the physical world that reaches him indirectly from the Web.
2. Our current implementation, due to the unavailability of open Google Earth clients for small devices, runs only on laptop computer. At the time of writing, we are working on the porting of our system and of related services on the J2ME client for Google Maps (www.google.com/glm), in order to use PDAs and cell phones instead of laptops. Also, we are confident open Google Earth clients for small PDAs will be released soon.

2.2 Services

To test our infrastructure, and experiment with the concept of browsing the world, we developed three services using the above technologies (see Fig. 2 for two snapshots).

Sensing the world. A first service allows a user equipped with a RFID reader and a GPS device to dynamically gather information about tagged objects (e.g., a relevant monument in a town), dynamically enrich the GIS representation of the environment with such acquired information (i.e., by adding and

visualizing a placemark representing the object in Google Earth), and automatically generating a Web query to gather more information about it. This service can be fruitfully employed in a number of situations. In particular, we focused on the scenario in which a tourist wants to automatically build and maintain a diary of his journey. To this end, the proposed service allows to keep track of all the user movements and have them displayed on the map of the visited places, together with the information about the monuments is has encountered.

The Marauder's Map. A user equipped with a GPS device can decide to share his location with other users and, analogously, he may wish to be aware of the location of others users. For example, a group of friends can share their actual GPS locations with each other (either by ad-hoc WiFi communications or by periodically downloading/uploading positions to a common server), and can display them on real-time a map (which, by the way, can highlight other interesting information for the group, such as museums or bar, depending on the specific interests of the group). This service may be useful in a variety of situations. Our current implementation of the service deal with privacy by leaving up to the individual user to decide whether to: share its position or not (and with which accuracy), make it available only to a restricted group of users, or to make it publicly available but only in an anonymous way.

Location dependent queries. A user can query for information about local facts and "things" (e.g., "Find all restaurants within 500 meters") and visualize the answer at the correct location (i.e., in the form of Google Earth placemarks). The query is executed by accessing placemarks shared by other users and made available to some placemark server as well as (if any is available) by accessing information coming directly from the physical world, and by integrating all of them. Since the answer to a location-dependent query is based on the location of the mobile users, the results of these queries dynamically change as the users change their location. This service, naturally complements the previous one. For example, we focused on supporting a group of tourists visiting a place cooperatively. Such a situation applies to a class of students or to a group of boy-scouts, where each person can visit the place independently, while keeping in touch and sharing information with the other members. To this end the service allows to share GPS data with other members and with the group leader, and placemarks pointed by one person may be shared across the whole group. This can be useful to share opinions or interesting sightings, but also to agree on some meeting points easily (e.g., by sharing placemarks, all the users can spot a suitable place that is in the middle of them and agree to meet there).

Figure 2. Proof-of-concept services: (top) sensing the world (bottom) mapping users and submitting location-dependent queries.

3. CONCLUSIONS AND RESEARCH DIRECTIONS

We are aware the research in this field is exploding (and the final version of this paper will properly account for related work), the same as it is exploding the amount of data about the world which is made available by pervasive computing technologies. So, on the one hand, it is very important to study all potential application areas and understand how these would impact on everyday activities. On the other hand, it is important to create better tools to produce, integrate and properly visualize in GIS an increasing amount of data. In particular, it would be interesting to devise new services to collect, aggregate a mine spatial data. Moreover, to make browsing the world truly ubiquitous, it would be important to develop novel user interface to let it possible visualizing rich spatial information on small displays and to make them easily accessible.

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